ON-ROAD MEASUREMENT OF EMISSIONS FROM HEAVY-DUTY DIESEL TRUCKS: IMPACTS OF FLEET TURNOVER AND ARB'S DRAYAGE TRUCK REGULATION

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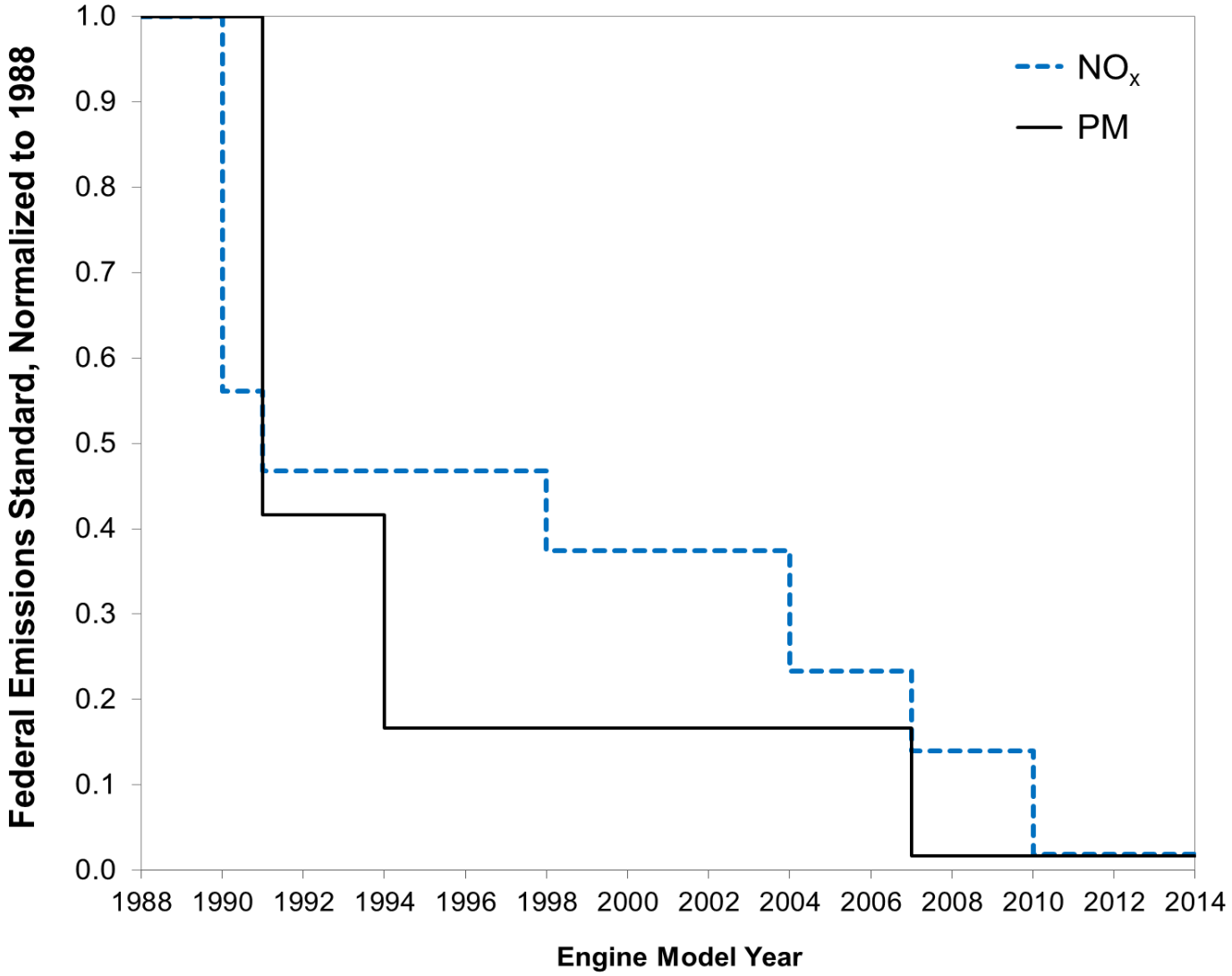
Introduction

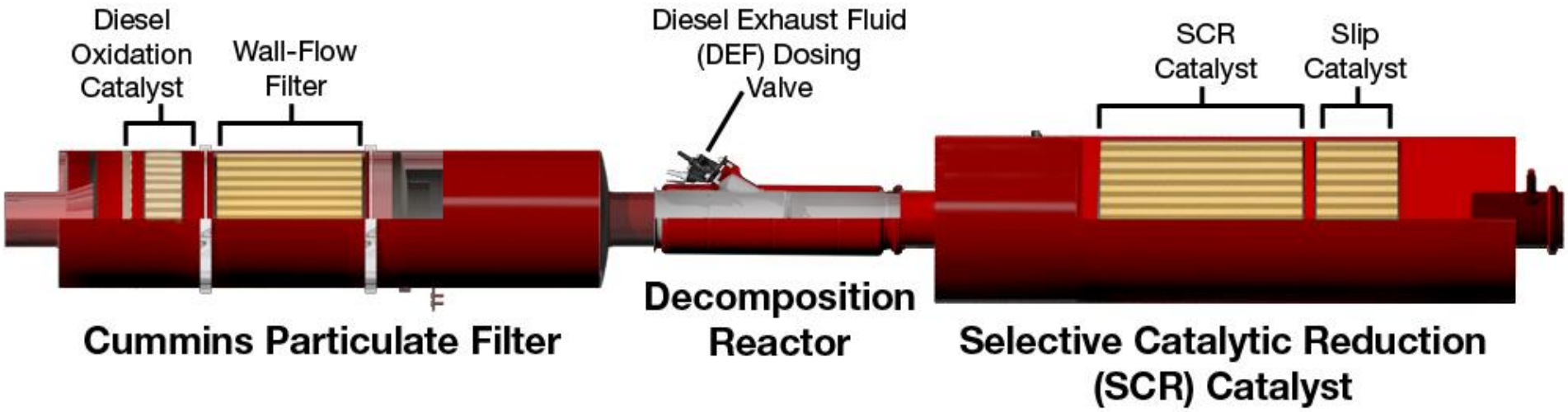
- Major efforts underway to reduce diesel emissions:
  - stringent emission standards for new engines
  - accelerated retrofit/replacement of California engines:
    - Widespread PM emission control by 2016
    - Near universal NO_x emission control by 2023
  - highly accelerated retrofit/replacement of trucks used for short-haul trips (“drayage”) to/from ports and rail yards

Heavy-Duty Diesel Emission Standards

(For New On-Road Truck Engines by Model Year)



Diesel Particle Filter (DPF) & Selective Catalytic Reduction (SCR)



Used on 2007 & newer engines
(DPF retrofits possible on older engines)

PM from engine exhaust trapped on filter

NO_2 oxidizes trapped carbon particles
(this helps to regenerate the filter)

Used on 2010 & newer engines
(SCR is difficult to add as a retrofit)

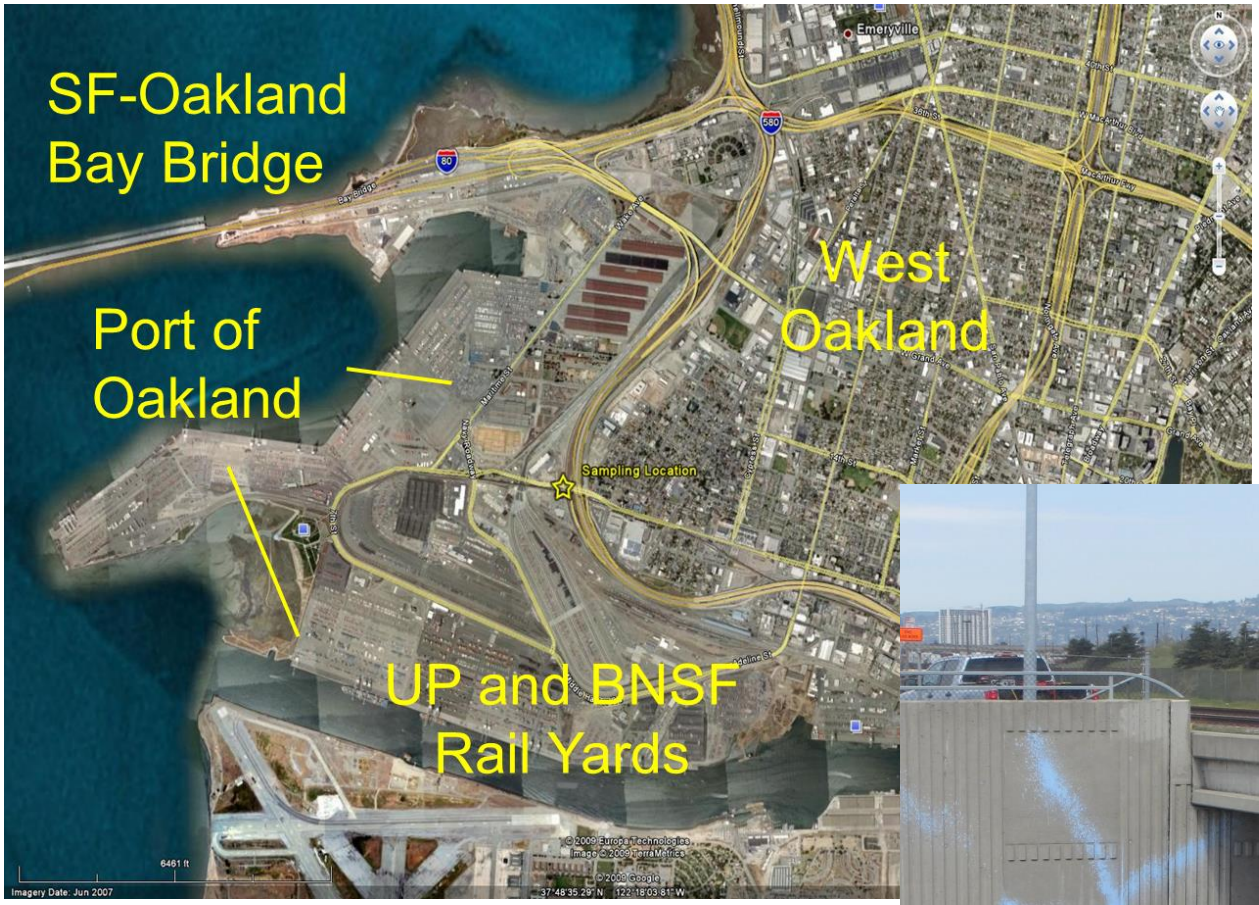
DEF = mixture of urea + water
Urea converted to 2 NH_3 + CO_2

NH_3 reacts with NO_x to form N_2

California Drayage Truck Regulation
(Based on Engine Model Year)

Deadline	Engine Banned	OK if Retrofit with Diesel Particle Filter (DPF)	Engine OK as is
Jan 2010	1993 & older	1994-2003	2004 & newer
Jan 2012	1993 & older	1994-2004	2005 & newer
Jan 2013	1993 & older	1994-2006	2007 & newer
Jan 2014	2006 & older	none	2007 & newer

Present study features measurements of in-use emissions from drayage trucks at the Port of Oakland in Nov 2011 and Mar 2013 (plus baseline data from Nov 2009)

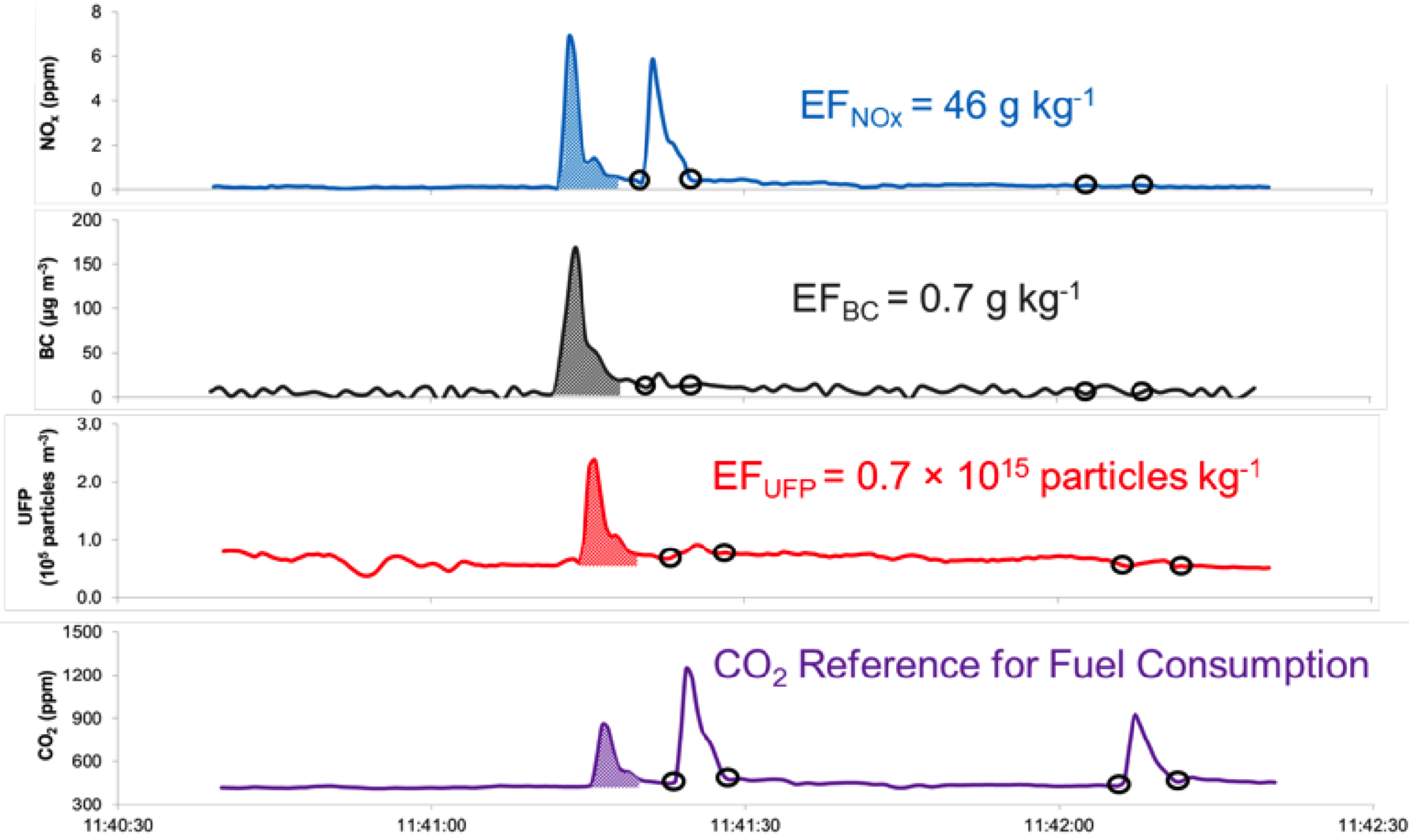

SF-Oakland
Bay Bridge
Port of
Oakland
West
Oakland
Sampling Location
UP and BNSF
Rail Yards
Emeryville
6461 ft
Imagery Date: Jun 2007


GVC
2412

Port of Oakland Field Measurements

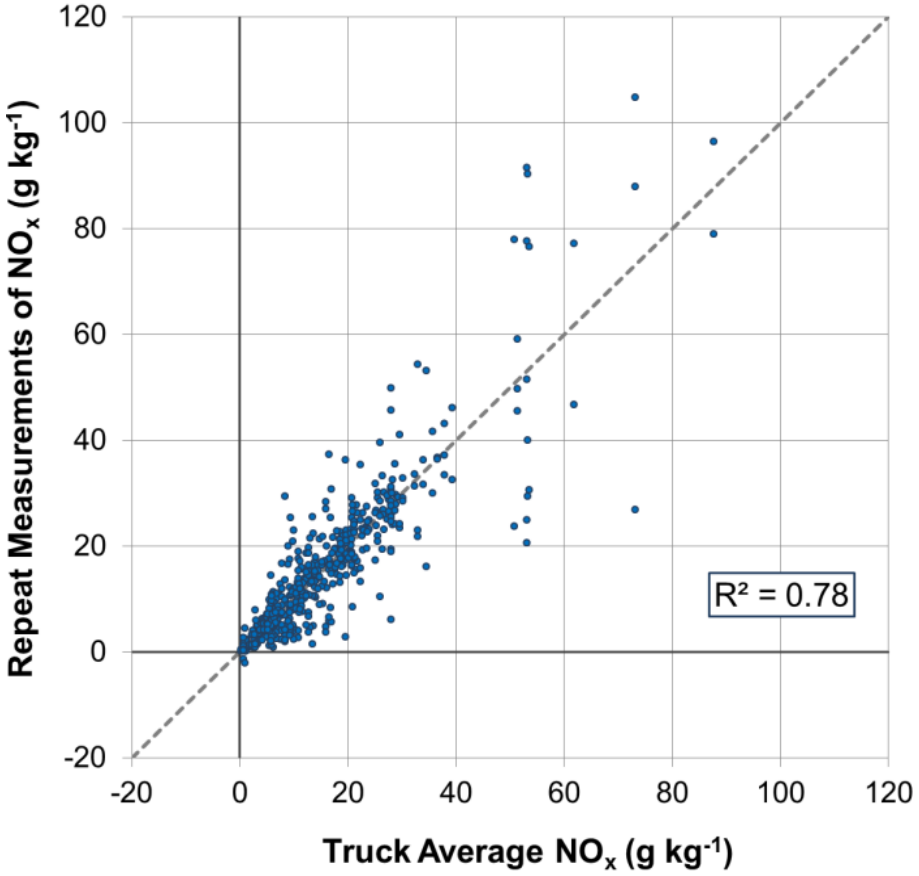
- Sample exhaust plumes of individual port trucks:
  - NO_x and NO_2 (by difference, NO_x – NO, using two analyzers)
  - Black carbon (BC by aethalometer – light absorption)
  - Ultrafine particles (UFP by condensation particle counter)
  - Particle size distribution (FMPS = Fast Mobility Particle Sizer)
  - CO_2 (by infrared absorption)
- Emission factors calculated by carbon balance
- License plate images used to obtain info about each truck
  - engine make & model year, retrofit control devices

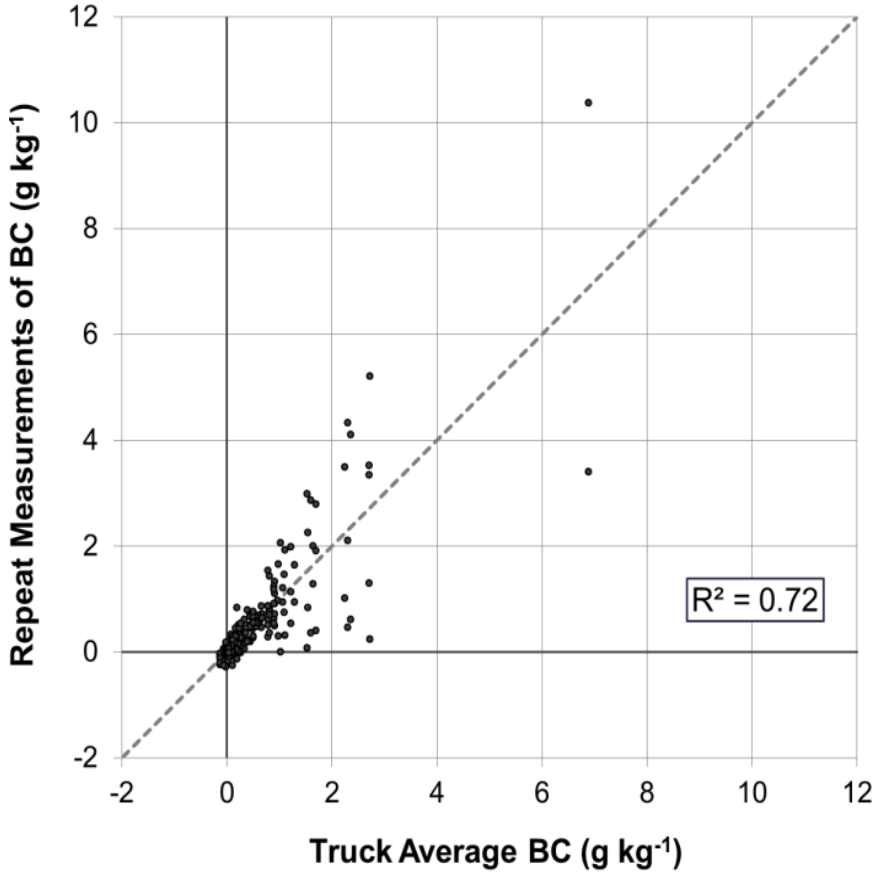
Emission Factor Calculation



NO_x & BC Emission Factor Repeatability

(Repeat Sampling of Emissions from 207 Trucks)

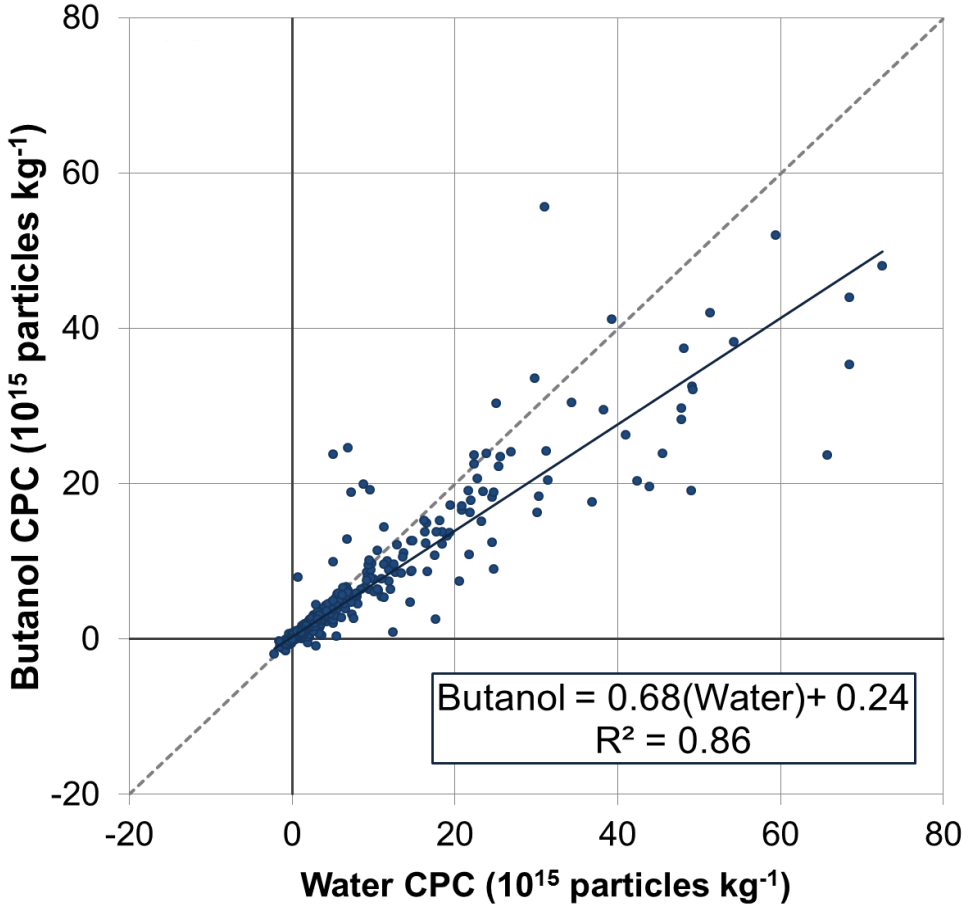


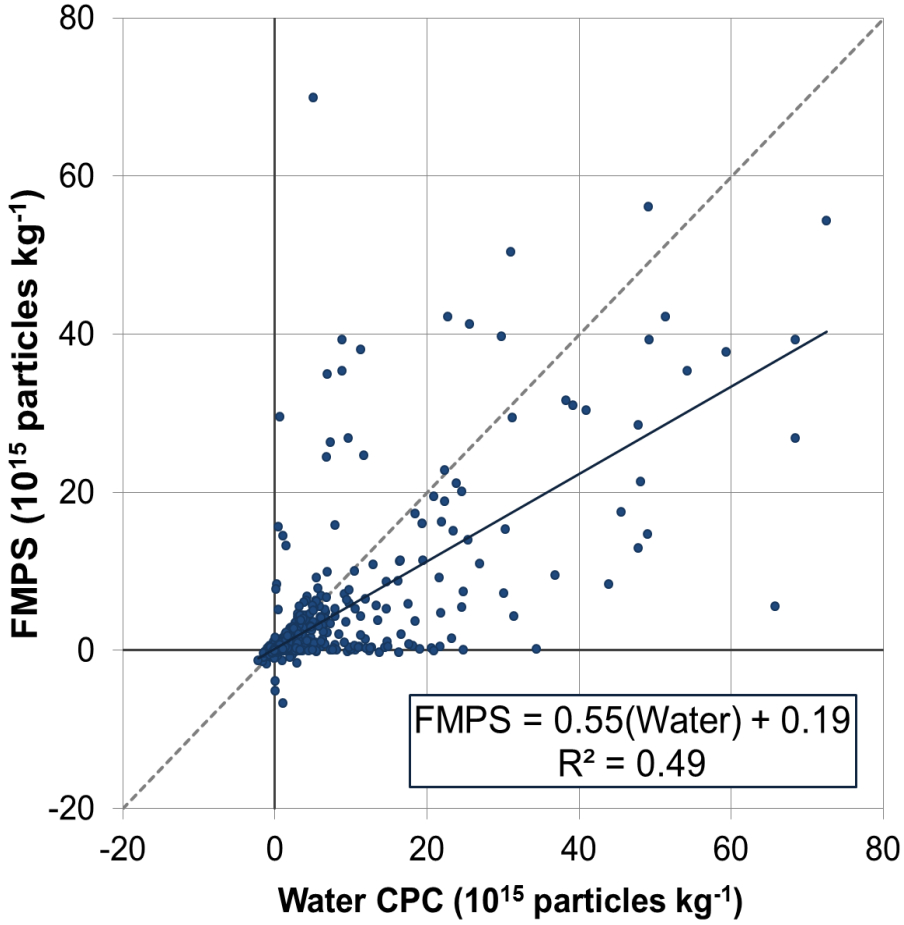


R^2 values not as high for NO_2 (0.60) and UFP (0.52)

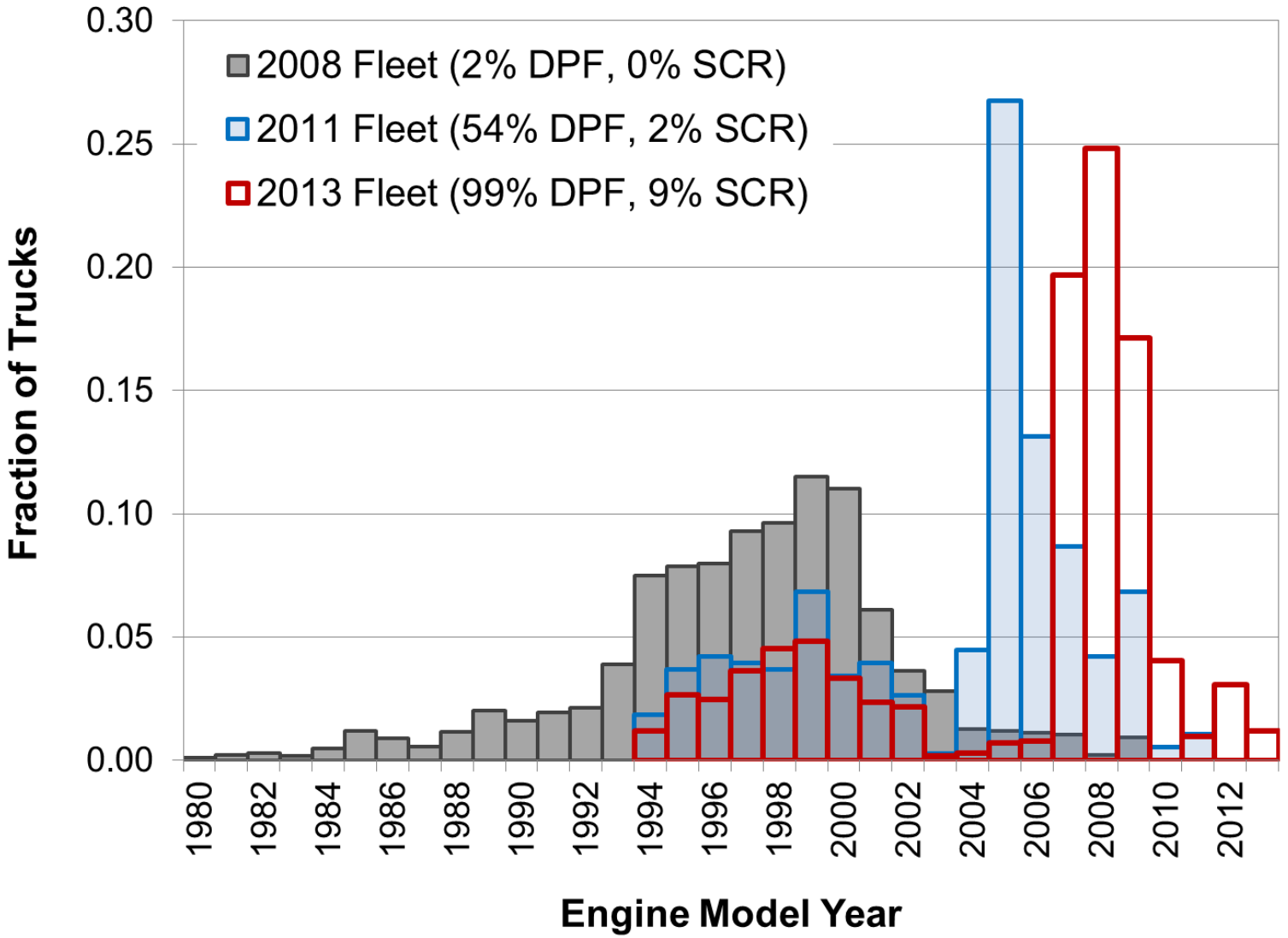
PN Emission Factor Repeatability

(Particle Number Emissions via Different Methods)



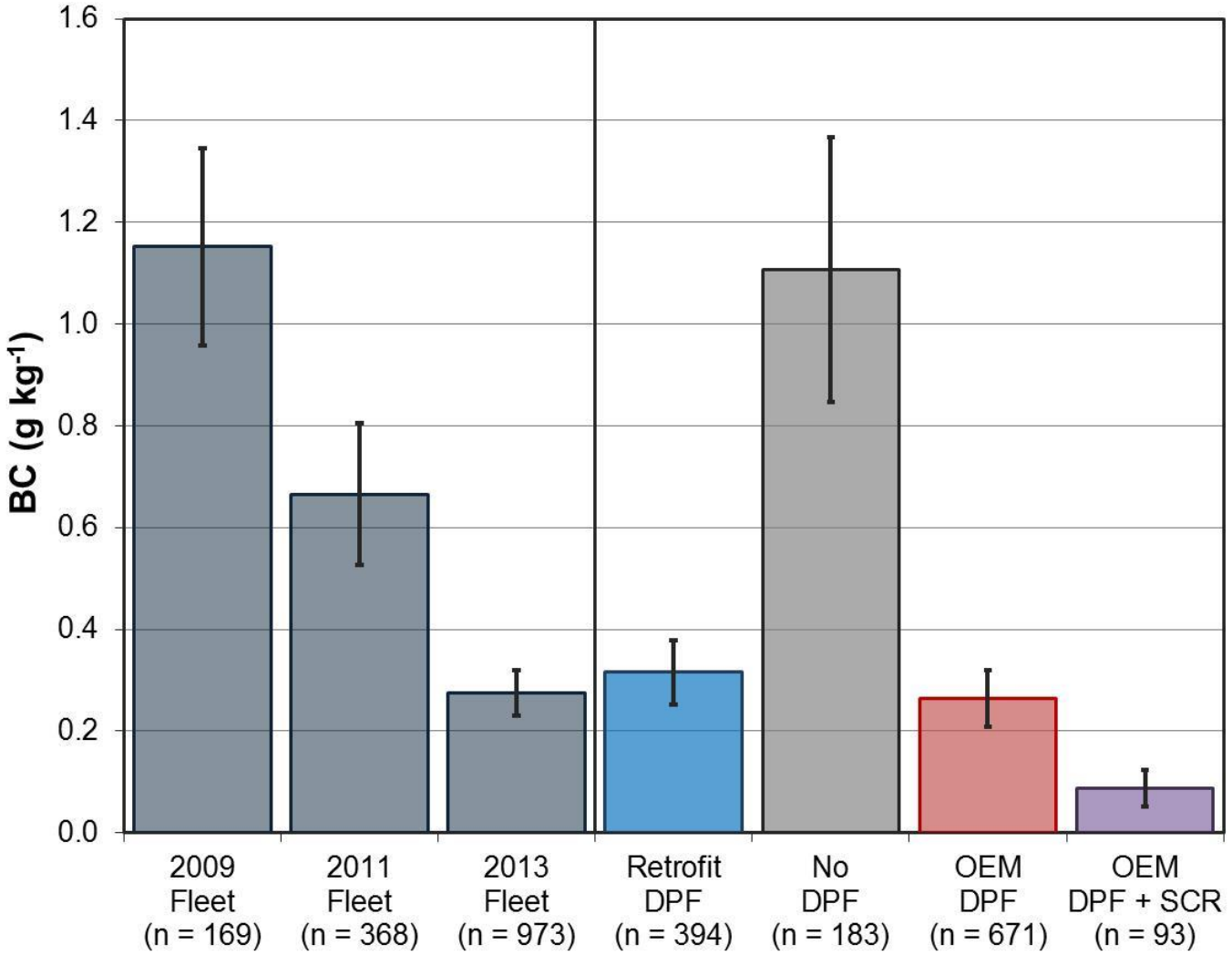


Port Truck Engine Age Distribution



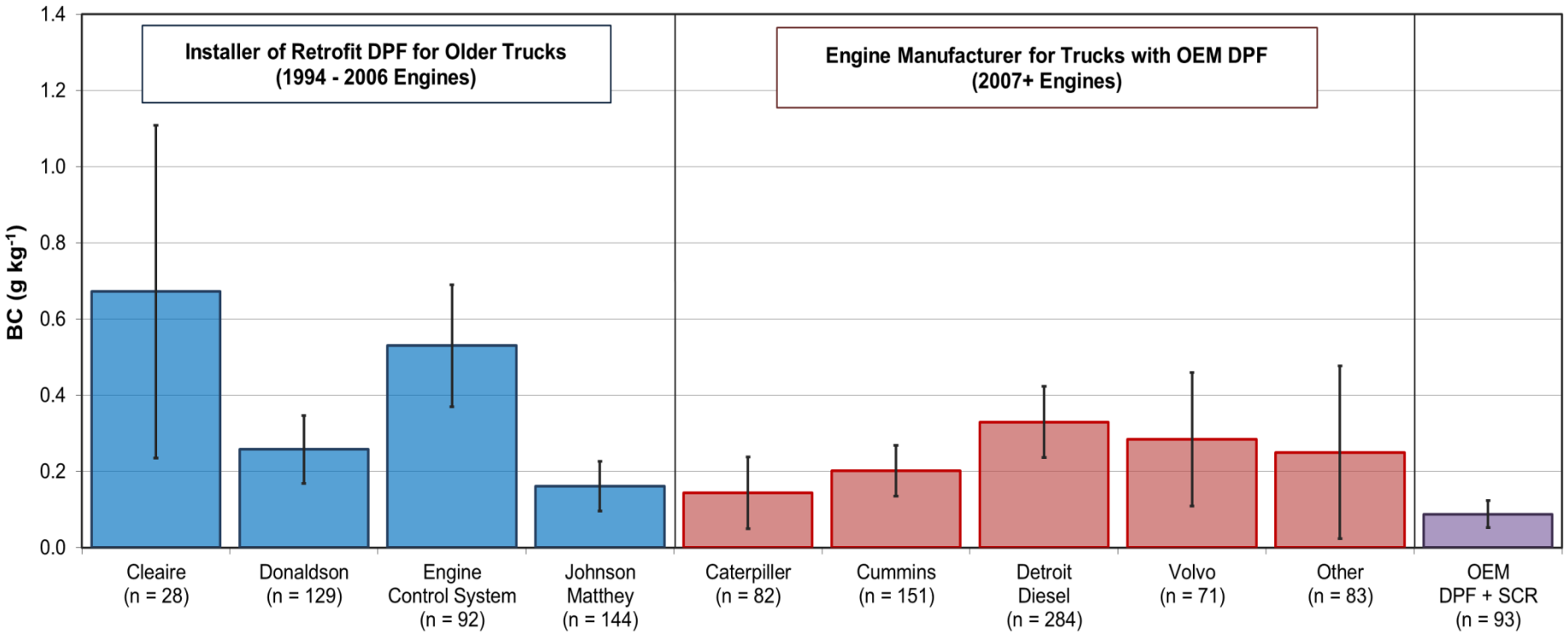
Black Carbon Emission Factors

Decreased by 76 ± 22% between 2009 and 2013



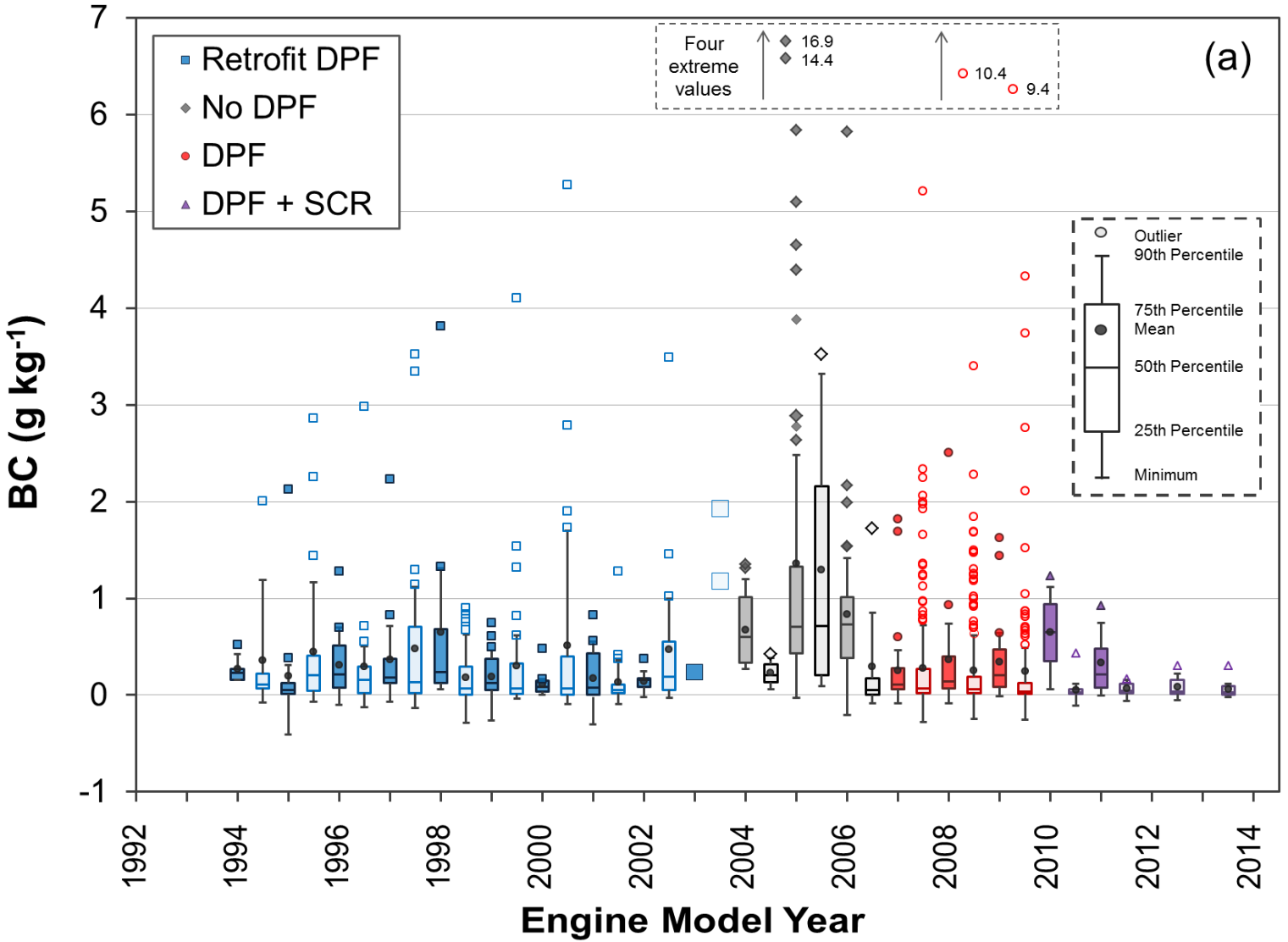
Black Carbon Emission Factors

By DPF Retrofit Installer (Blue) or Engine Manufacturer (Red)

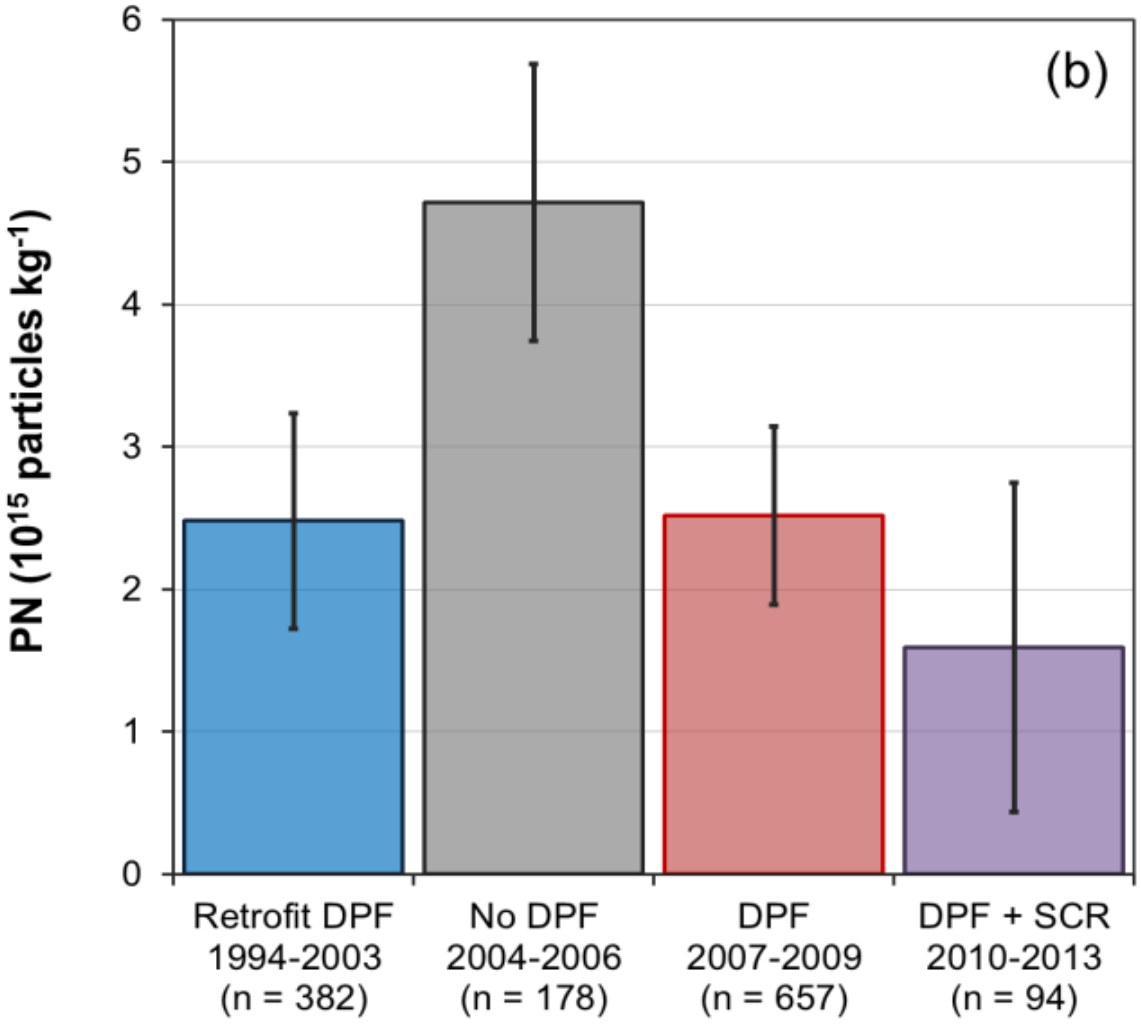


Black Carbon Emission Factors

Box-Whisker Plots by Engine Model Year

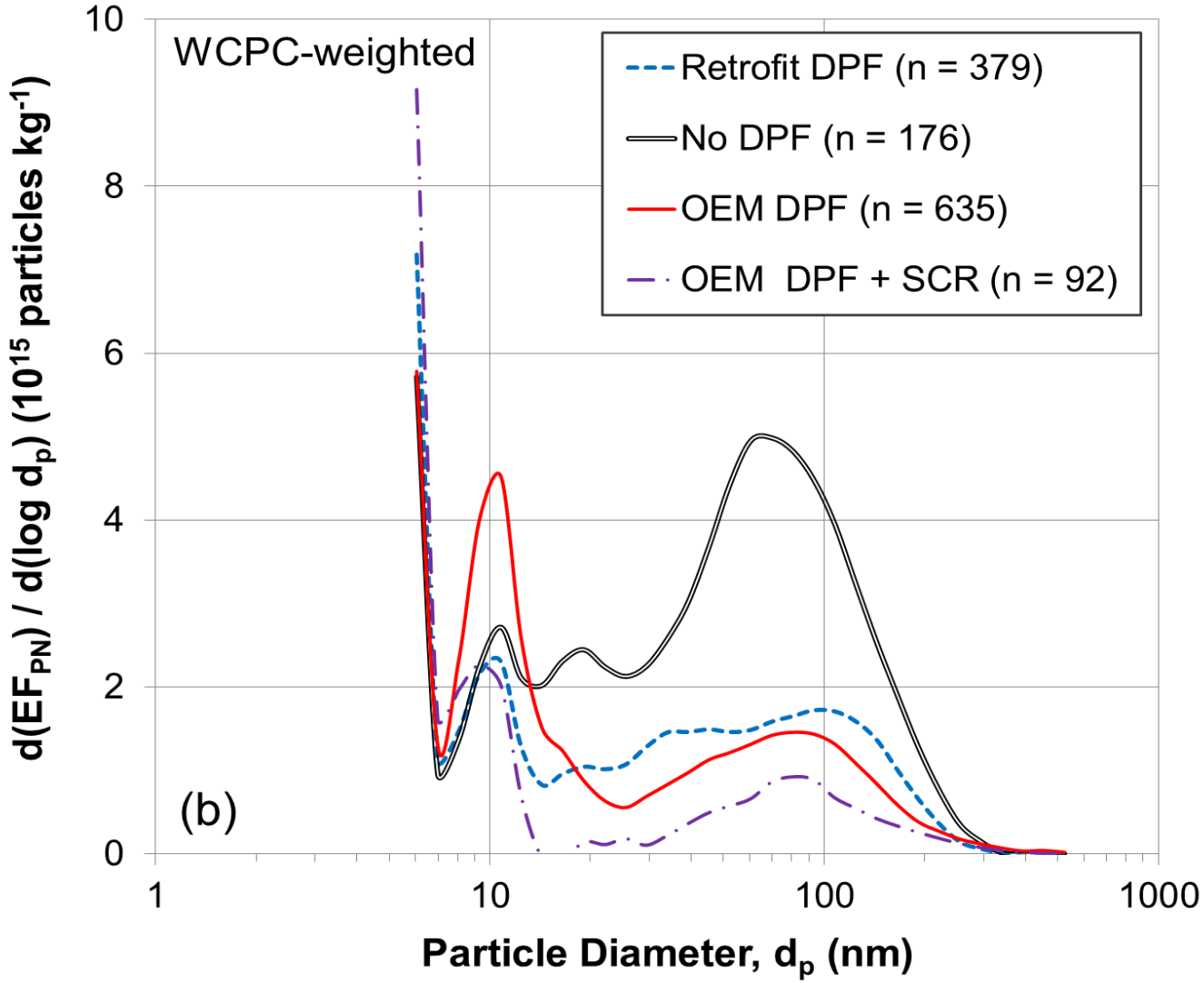


Particle Number Emission Factors



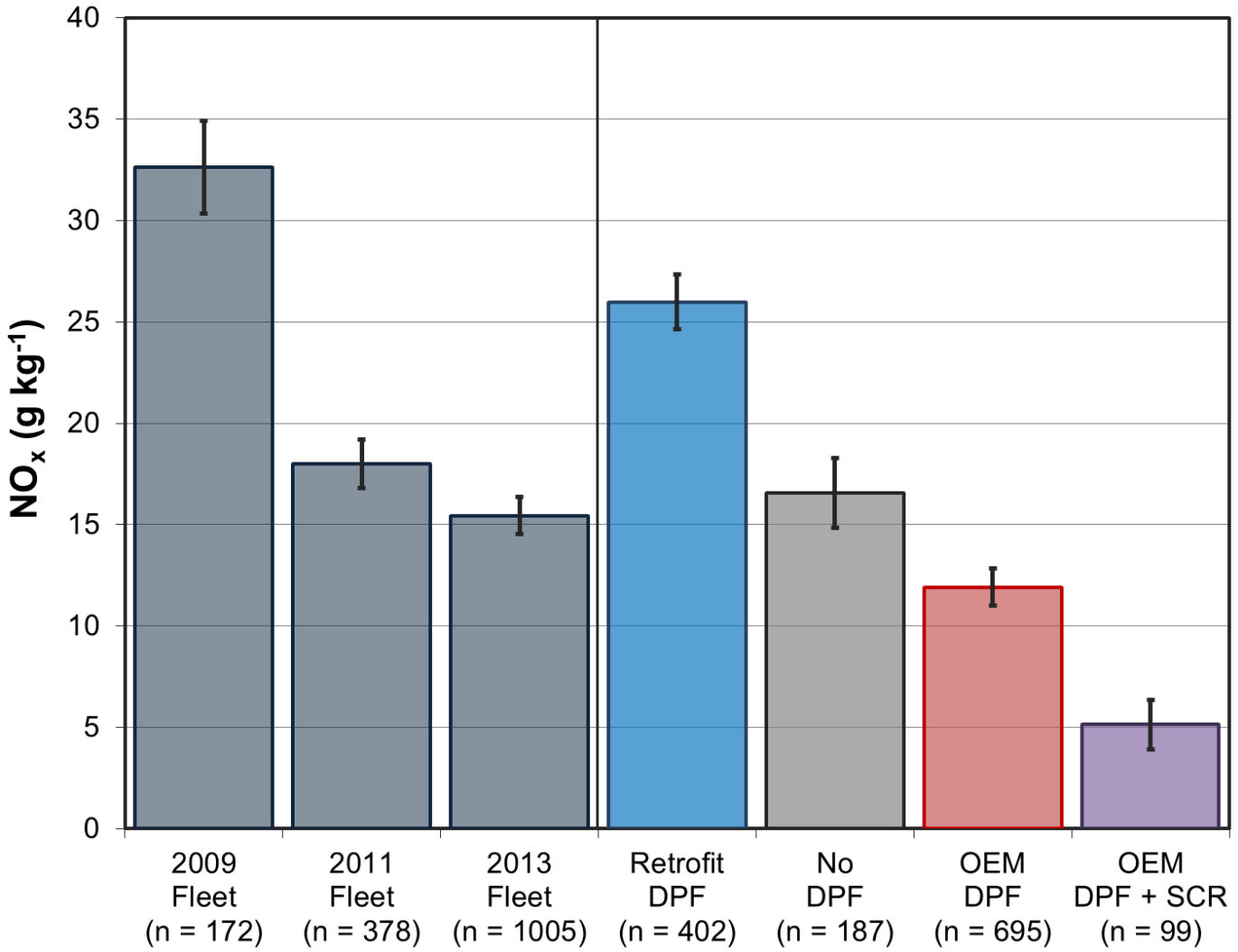
Particle Number Size Distributions

Measured Using FMPS

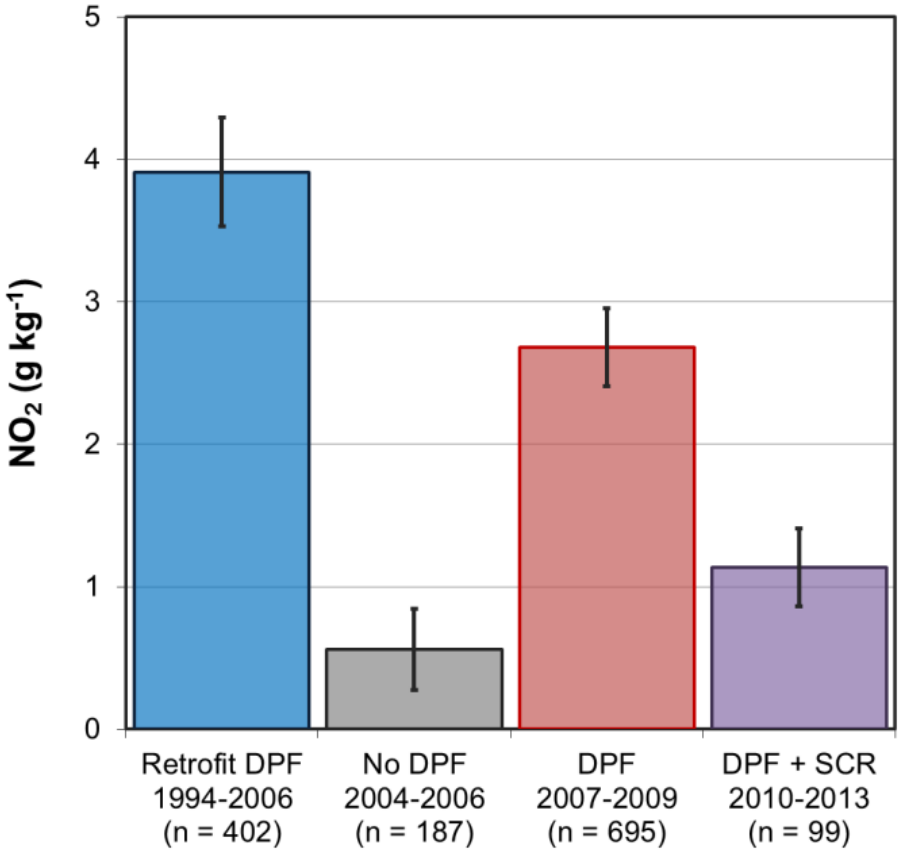


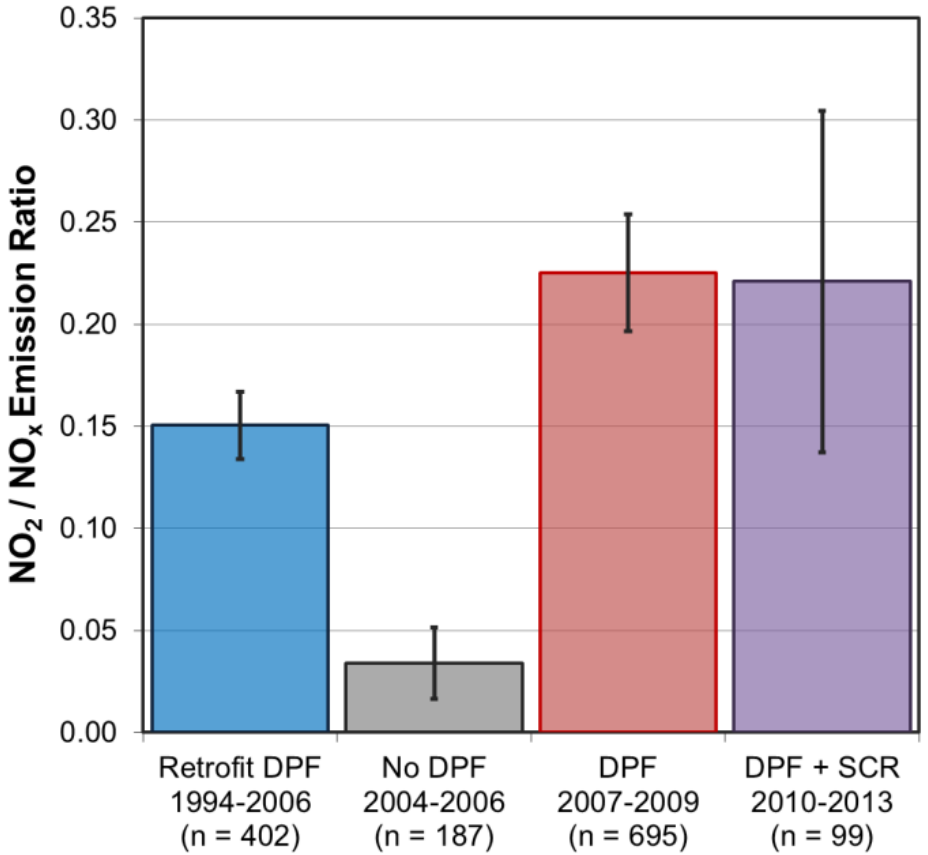
NO_x Emission Factors

Decreased by 53 ± 8% between 2009 and 2013

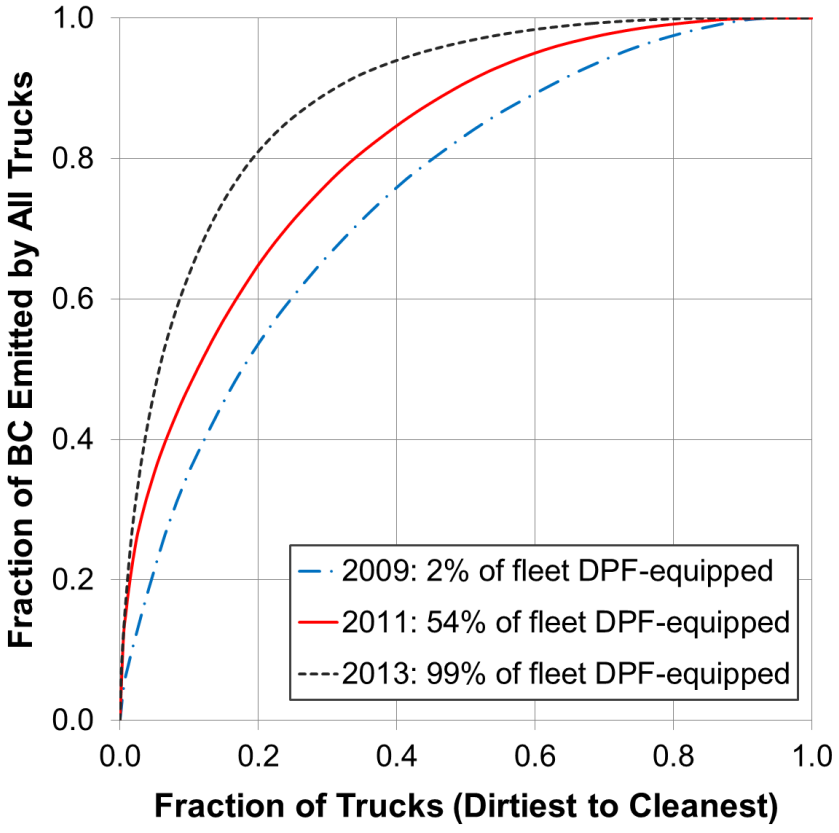


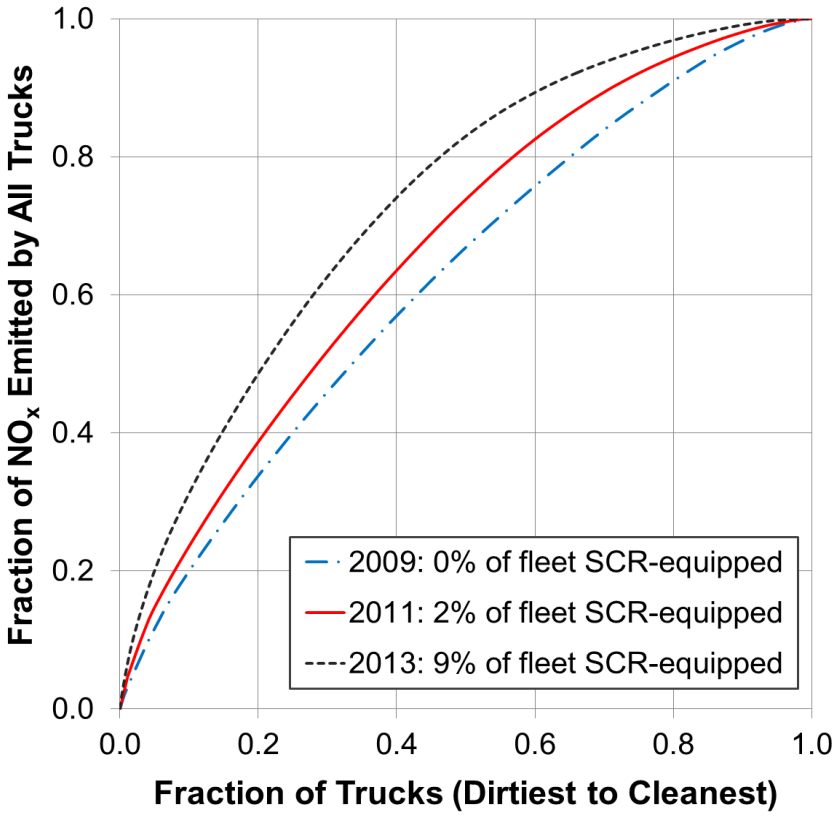
NO_2 Emfacs and NO_2/NO_x Ratio





High-Emitter Contributions to BC & NO_x





Summary of Key Findings

- Between Nov 2009 and Mar 2013, fleet-avg emission factors for Port trucks changed as follows:
  - BC decreased by 76 ± 22%
  - NO_x decreased by 53 ± 8%
  - NO_2 increased from 3 to 18% of total NO_x emissions
  - These emission changes were rapid compared to what would have been achieved based on natural fleet turnover alone

- Use of DPF led to decreases in particle number emissions
  - Some trucks measured in 2011 (2004-06 engines) had no DPF
    - Higher PN emission factors compared to DPF-equipped trucks

Discussion

- Further Plans for Measuring Diesel Truck Emissions
  - Caldecott Tunnel: summers 2014, 2015, 2017 (contract 12-315)
  - Port of Oakland: summer 2015
- Mitigating DPF-Related Increase in NO_2 Emissions
  - SCR for NO_x control helpful in reducing primary NO_2 emissions
- Pros and Cons of DPF Retrofits vs. Truck Replacement
- How Will Truck Owners Comply with Truck & Bus Rule?
  - Insights based on what we saw at Port of Oakland

Pros and Cons of DPF Retrofits

ADVANTAGES

- Cost effectiveness in achieving primary PM emission reductions
- Old truck is fixed rather than exported, leading to global as well as local AQ improvement

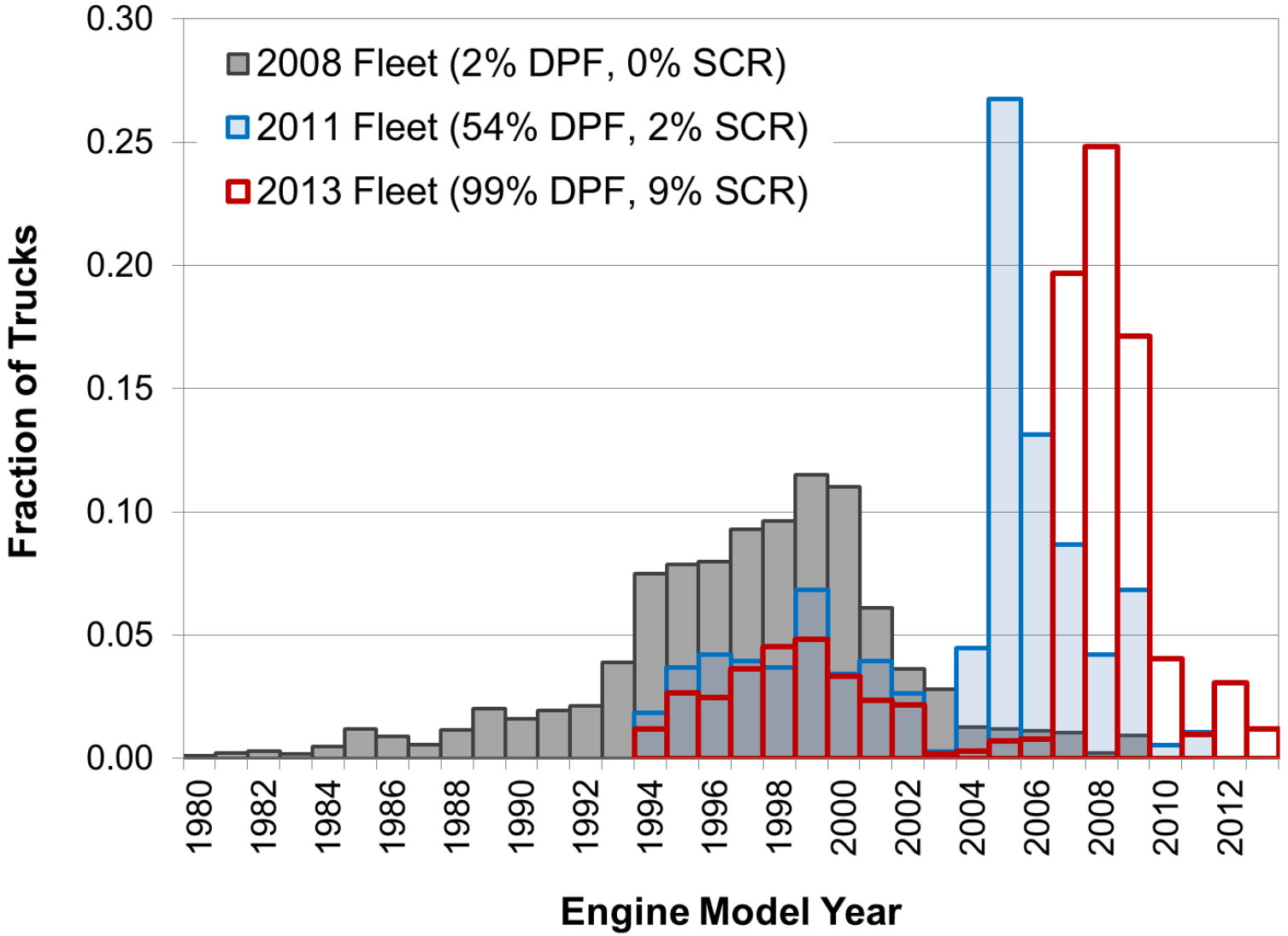
DISADVANTAGES

- DPF does not help to control NO_x emissions
- Retrofits of older trucks with higher baseline NO_x emissions lead to larger & undesired increases in primary NO_2 emissions

Port of Los Angeles/Long Beach did wholesale replacement of drayage truck fleet (paid for by container fee imposed on shippers)

Port of Oakland saw a significant number of DPF retrofits on 1994-2003 engines

Truck and Bus Rule Compliance Strategy: Purchase Used Trucks, 2007-2009 Engines



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